THE RELATION OF CHANGING TECHNOLOGICAL EFFICIENCY TO PRICES AND PAYMENTS TO THE PRODUCTION FACTORS IN THE FLOUR AND OTHER GRAIN-MILL PRODUCTS INDUSTRY, 1909-1935

BY

ROSCOE RAYMOND GIFFIN, JR.

B. S., University of Illinois, 1936
M. S., University of Illinois, 1937

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SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ECONOMICS
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URBANA, ILLINOIS
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Description of the Study

The problem of this study is to describe and explain the relation of changing technological efficiency to prices and payments to the production factors in the flour and other grain-mill products industry for the period 1909-35.

Interest in problems of unemployment has produced a number of studies which are concerned with technology in relation to the volume of labor utilized. In a few cases changes in the quantities of labor required have been related to prices and payments to the factors of production.

In this study an attempt is made to broaden this general type of analysis by including an estimate of the physical input of capital as well as that of labor, and by a closer examination of efficiency and prices. The general methodology used to accomplish these objectives was developed by F. C. Mills.

The particular attribute of technology whose influence on prices and income payments is here being studied has to do with the utilization of the physical input of the factors of production. The measurement of its aspect of technology is based on the concept of efficiency. Changes in efficiency are accompanied by changes both in the amount and proportions of the factors of production; as a consequence conditions are established both for changes in prices and in the pattern of income payments.

The analysis is limited to a specific segment of the entire production structure of grain products. This group is in the manufacturing phase of production and is termed the "processors." The analysis of price relations is concerned with that specific group of buyers who purchase directly from the mills; this group is termed the "distributors".

The basic data for the study have been obtained from various volumes of the **Census of Manufactures.** Supplementary statistics have been taken from a large number of other sources too numerous to be mentioned in this limited summary. Among these additional references the most valuable is an unpublished study made by the National Research Project in cooperation with the National Bureau of Economic Research: **A Study of Changing Employment in the Flour Milling Industry in the United States.**

Eficiency of the Industry

Concepts

The term "efficiency" usually has reference to certain output and input ratios which measure the result flowing from a given activity. For the specific problem of this study the engineering or physical concept of efficiency has been adopted. The output or work accomplished is measured by an index of the physical volume of production of the industry, using weights applicable to the objectives of the study. The input is a measure of the physical contribution of the factors of producton.

In other studies similar in character to this, the physical input of the human factor is measured through employment or manours. Many of these analyses make no attempt to measure the input of the capital factor. Current studies which aim at estimates of capital contribution in a physical sense usually are based on the concept of embodied labor as it has been developed by such writers as Locke, Ricardo, Marx, and Bohm-Bawerk.

The input of the employees of the industry has been measured in this study as man-hours of labor time and is a rough approximation to human energy utilized in production. As for the physical contribution of capital we have deviated from the measurement of embodied labor and have employed estimates of that inanimate energy which is applied through capital equipment, expressed statistically as the kilowatt-hour. Producer capital of the highly specialized type employed in flour milling is thus viewed as a means by which vast amounts of inanimate energy are applied to the task of processing raw grains. The "dose" or input of capital is measured as a unit of inanimate energy instead of human labor. Reasons for using this method are presented as follows.

The attempts of various writers in theory to explain the productiveness of capital equipment used in manufacturing have culminated principally in the writings of Bohm-Bawerk. His explanation was largely in terms of showing what the components of physical capital are. These he reduced to humah labor and land (natural resources), combined through the willingness of the owner to wait for the deferred product. The physical contribution is thus what capital is—a synthesis of labor, land, and waiting.

The explanation of the productiveness of capital in terms of embodied labor overlooks what is probably the most significant development of the physical sciences in relation to manufacturing — that of applying vast quantities of energy derived from natural resources to the problem of doing that work necessary to the processing of raw materials. It is the factor of energy rather than the accumulation of human labor which is probably the principal physical explanation of the great increase in production since the period of the Industrial Revolution. The physical input has thus been measured in terms of what capital does rather than of what capital is composed.

Statistical description

Since the measure of efficiency is the ratio of physical output to physical energy input, it was necessary to construct an index of physical production and an index of total applied energy.

To construct the production index, measures of output of wheat flour, bran and middlings, feed and screenings, rye flour, buckwheat flour, cornmeal and corn flour were combined. Since interest in this study centered on the relation of the volume of output to the volume of physical energy, the weighting system used to combine the output of the separate products into one average figure was based on energy requirements of each commodity.

The measure of human energy or labor time necessitated adjustment of employment data for changes in hours of work per man per year. Man-hours have been used rather than employment data because the latter overstate labor time during periods of changing hours of work.

Inanimate energy is derived from coal, combustion engines, water power, and purchased electricity. The KWH of applied energy derived from coal and purchased electricity were estimated by divisionof the money expenditure of the industry for each of these sources by per unit prices for each. It was thus possible to determine tons of coal purchased and to then convert the results into applied KWH through estimates of thermal efficiency. KWH obtained from purchased electricity were estimated directly by division of costs by power rates. Since data were lacking with which to estimate KWH derived from water power and combustion engines, the estimates for coal and electricity were adjusted on the basis of the proportion which the other sources were of total installed horsepower in the industry.

The measure of man-hours and aplied KWH were combined into one index of applied energy on the basis of weights computed from the ratio of the two series.

The efficiency measures are shown in Table 1. There has been considerable advance in the volume of output associated with each unit of energy-output as is indicated by the fact that on a basis of 1909 as 100 the efficiency ratio was 162 in 1935. Relative to 1909 the indexes of both output and input have decreased as of 1935, but that of energy has declined the most.

Explanatory factors

Man-hours of labor time have shown a marked drop of approximately 50 percent between 1909 and 1935. In attempting to analyze this change into its explanatory elements, the principal factors to consider are the substitution of inanimate for human energy and the concentration of output in large plants whose labor requirements are considerably lower than those of small plants. For each manhour in 1909 the industry used about 8.5 KWH. By 1935 the ratio was approximately 10 to 1. Mills of capacity of 100,000 barrels and over per year accounted for 54 percent of the industry output in 1909; in 1935 80 per cent was in the hands of such mills. Large-plant labor requirements per barrel of output are considerably less than those of small mills.

KWH of applied energy dropped approximately 40 per cent between 1909 and 1935. The principal elements of the explanation are the changes in methods of power application and the shift in output concentration to large plants. Technical developments

have gone in the direction of individual electric motor installations for the milling units instead of the application of power derived from reciprocating steam engines or water wheels through the overhead belt system. Very significant power economies can be obtained through individual motor installations and purchase of electric power. The economies of large-scale operation are also apparent in the difference in power costs per unit of output as between large and small plants. This factor has attained considerable importance with the shift to large plants.

Efficiency and Prices

Statistical description

The method of analyzing the relation of efficiency changes and prices is based on measures of real costs paid by distributors and real income received by processors. Five basic measures are necessary:

Q — physical output
E — energy input
S — value-added
P_1 — prices of goods and services sold by distributors
P_2 — prices of goods and services purchased by processors

Several of the ratios obtained from these measures are shown in Table 1. Four of them are described here as a means of defining the distribution of the gains from efficiency as between distributors and processors.

The two price indexes serve to pass from the level of money income and money cost to that of real income and real cost. The real income of processors is approximated by division of value-added by prices of goods and services purchased. The real cost to distributors of the services of processors is approximated by division of value-added by prices of goods and services sold by distributors. When the real income of processors is reduced to a per unit of energy basis, a comparison is thereby made of the exchange power of the energy input of processors for the goods and services which they purchase. By reducing the real money cost to a per unit of goods produced basis, a comparison is made of the bargaining power of processors services for the goods and services sold by distributors.

It is clear that real unit rewards of processors did not move with changes in efficiency until about 1927. Since then they have been increasing more rapidly than the measure of efficiency. Evidently little of the reduction in energy requirements was retained by processors up to 1927. Their gain since 1927 has been more rapid than that of efficiency.

The measure of technological changes which is used in relation to unit costs paid by distributors is the reciprocal of the efficiency index — the ratio of energy input to physical output— and is termed "unit energy requirements".

Unit energy requirements and real costs per unit of output to distributors moved with a fair degree of similarity until 1927, although costs went down less than energy. From 1927 through 1935 unit energy requirements declined quite rapidly while unit real costs paid by distributors showed some trend increase. Evidently, considerable portion of the reduction in energy requirements was being passed on to distributors in the form of lower prices until about 1927. From 1927 through 1935 the bargaining power of processors' services ceased to decline relative to goods and services sld by distributors and showed a tendency to increase, despite the sharp drop in enery requirements.

Explanatory factors

The exchange power of processors services for other commodities may be expected to decline as a result of the action of such forces as shifts to the left in the demand curve; reductions in production costs being passed on to distributors; and operation of capacities developed for a larger total demand.

Per capita domestic consumption of flour has been declining since 1909, although during the 1920's there was little change. Following 1929 there was a rather sharp drop. In terms of demand curves the lowering of per capita consumption may be depicted as a series of shifts to the left. The most rapid fall in real unit costs paid by distributors came between 1919 and 1925 and may be attributable to the operation of capacities installed for the peak production of the war period. As long as the structure of the industry remained basically competitive it is to be expected that some of the cost reductions made possible by substitution of cheaper production factors (evidenced by ratio of KWH to man-hours) would be passed on to distributors in the

Table I.Some Indexes Relevant to Processors and Distributors

Year	Processors		Distributors	
	Efficiency Q/E	Unit Real Income S2/E	Unit energy Requirements E/Q	Unit Real Costs S1/Q
1909	100.0	100.0	100.0	100.0
1914	107.6	93.2	92.9	95.7
1919	111.5	99.7	89.7	107.8
1921	130.8	108.1	76.5	84.3
1923	132.2	96.1	75.6	76.7
1925	133.3	100.0	75.0	79.0
1927	128.8	97.7	77.6	81.4
1929	148.3	122.8	67.4	89.0
1931	158.1	113.0	63.3	73.7
1933	153.1	140.3	65.3	83.5
1935	162.1	136.9	61.7	77.2

form of lower prices. There is evidence to indicate that the structure of the industry became dominantly monopolistic-competitive during the 1920's.

Some of the reduction in exchange power may be checked by reducing output and by obstructing the action of competitive forces. On a basis of 1909 as 100 the index varied between a low of 102 and a high of 107.5. In 1933 and 1935 the index was approximately 91. The pronounced reduction in the number of establishments in the industry since 1919 represents elimination of some of the capacity used to meet the needs of the war period.

One phase of the industry's attempts to adjust to shifts in demand is represented by the development of devices for controlling the volume of output and prices. Various studies by the Federal Trade Commission have shown the presence within the industry of a strong movement, guided by its trade association "The National Millers' Federation," to stabilize prices and control output. This movement gained impetus during the early part of the decade following the war, and it appears to be significantly related to stabilization and slight trend increase in real unit costs to distributors following 1925.

The exchange power of physical input of processors for the goods and services they purchased remained fairly stable until about 1927, after which a marked increase took place. An increase in this measure may be expected under the conditions of (1) a reduction in energy-input at a more rapid rate than the decline in output; and (2) an increase in the exchange ratio between the products of the industry and the goods and services purchased. The exchange ratio declined rather steadily from 1909 to 1923 but has since then shown a tendency to increase, although not returningto the base year relation. However, the decline in the energy input, especially since 1927, is the principal explanation of the increase in unit real rewards of processors.

Efficiency and Payments to the Production Factors

Statistical Description

For purpose of this analysis the production factors are considered to be wage-earners, salaried employees ,and capital. The payment going to capital is treated as the difference between value-added and wages and salaries. This is, of course, a gross payment which is distributed as charges for depreciation, maintenance and repairs, taxes, business savings, interest, and dividends.

The method of comparing efficiency changes and payments to the various factors involves the following measures in each case: physical output, energy-input of all factors, money payment to the specific factor, and prices of goods and services purchased. From these measures a number of ratios are derived, but for this summary only those defining efficiency, total real income, and real income per unit of energy-input are used.

Comparison of real unit rewards of each factor with the overall efficiency measure for the industry is necessary because of the impossibility of determining an efficiency measure for each factor when all other elements are held constant. That is, although the energy-input of each factor can be aproximated, the portion of physical output attributable to it cannot be determined statistically.

Index numbers relating to efficiency and real income per unit of energy-input of each factor are shown in Table 2. The separate comparisons show several interesting and distinctive features. Unit real rewards of the salaried group are correlated to a high degree with efficiency since 1919 (both in terms of trend and deviations). Unit real rewards of wage-earners show approximately the same trend as efficiency but are not characterized by the rather sharp increases and plateaus typical of the efficiency series. Unit real rewards going to capital are characterized by considerable deviation and bear little relation to the efficiency measure. Up to 1923 the unit reward of this factor was decreasing in contrast to the marked rise in efficiency. But beginning with this year, real unit income of capital has increased rapidly from 84 in 1923 to 139 in 1935. This increase is much more rapid than the advance in efficiency.

Table 2. Indexes of Efficiency and Unit Real Income of the Production Factors

Year	Production Factors			
	Efficiency Q/E	Wage-Earners W_2/E_w	Salaried Employees O_2/E_o	Capital C_2/E_c
1909	100.0	100.0	100.0	100.0
1914	107.6	96.0	100.3	98.5
1919	111.5	105.0	85.5	96.7
1921	130.8	117.5	101.4	107.7
1923	132.2	119.9	108.7	84.2
1925	133.3	123.4	110.7	96.0
1927	128.8	125.4	114.5	97.7
1929	148.3	133.9	126.6	132.1
1931	158.1	139.4	148.0	115.0
1933	153.1	144.7	158.7	152.6
1935	162.1	156.6	163.5	139.3

The secular decline of the industry is illustrated by the fact that total real income of each factor was less in 1936 than in 1909. Payments to wage earners and salaried employees reached their peak in 1919 and have shown a tendency to a steady decline since then. The peak of payments to capital was also in 1919 but from the low point of 1923 there has been an upward trend.

Relative to total real income of the industry, the real income of both labor groups was highest in 1923, and has since declined considerably. Real income of the capital factor, relative to real income of the industry, reached its low point in 1923 and has since then increased gradually.

Explanatory factors

Although a number of interesting questions are left unanswered, it has been beyond the scope of this study to develop a satisfactory explanation of the relation of changes in efficiency to real unit payments to each of the factors. This is particularly true as regards differences in the patterns for wage-earners and salary workers. The general similarity in the movements of efficiency and real unit income of each factor can be explained in terms of the trend reduction in the input of each factor at a rate more rapid than the decline in output and total real income of the industry. The number of factor-units between which the income of the industry is to be divided has been declining.

Total real income of both wage-earners and salary workers has declined mainly as a result of reductions in the quantities of labor time utilized by the industry. Although real rates of pay were increasing, the advances were not sufficient to prevent the payments to these agents from declining.

Money rates of pay have increased at a much more rapid rate than the cost of living and as a consequence real rates of pay of both wage-earners and salaried employees have increased. These advances appear to be a part of the general increase enjoyed by these labor categories throughout the economy. A major element in the explanation is the scarcity position of each unit of labor time as the units of inanimate energy increase. The output which can be produced within a given man-hour increases as the available energy increases. Growth of physical output at a rate more rapid than that of the laboring force affords a

basis for an increase in the per unit exchange power of labor. With regard to the wage-earner group, trade unionism appears to have had little effect in this industry until 1933; some of the increase since this time seems to be assignable to growth of unionization.

Since the return to capital is treated as a gross residual there is no market price involved. The determinants of total money income share of capital are thus the substitution of inanimate for human energy (which reduces payments to the labor factor), and changes in the price and quantity relations of the services of the industry. Differences in cost alternatives are the determining factor in the substitution of capital for labor, but as to what have been the alternatives in this industry adequate data are lacking. Because the payment to capital is a residual, factors affecting changes in real value-added (real income of the processors) are an important determinent; they are described on pages oo – oo.

VITA

The writer, Roscoe Raymond Giffin, Jr., was born January 1, 1914, in Grand Junction, Colorado, and lived in this city until 1934. His elementary, high school and junior college education were obtained in the public schools of this city. In 1934 he enrolled as a junior in the University of Illinois. This institution granted him the degree of B. S. in Education with honors in Economics in 1936. During the academic year of 1936-37 he held a scholarship in the Economics of Public Utilities at the same university and received the degree of M.S. in Economics. During the remainder of the year 1937 and part of 1938 he was employed in the offices of the J. T. Ryerson Steel Company of Chicago. He then returned to the University of Illinois as an assistant in the Bureau of Business Research. The summer of 1938 was spent in study at the University of Wisconsin. From this time until 1941 he has been a teaching assistant at the University of Illinois. The preparation of this study was made during the period from the summer of 1940 to the fall of 1941.

He has one publication: Appendix I. "Some Statistical Tools Used in Sampling", in Saunders, A. G. and C. R. Anderson, **Business Reports,** 2 ed., McGraw-Hill Book Company, Inc., 1940, New York and London.